INDUSTRIAL GOVERNANCE AND POLICY LEARNING:

THE CASE OF GERMAN TECHNOLOGY POLICY

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The concept of industrial governance structures has proven increasingly attractive to political scientists in recent years.[1] The new-found interest has causes outside as well as within debates in the field. Among external events, the end of the Cold War removed the opposition of market economies and central planning as a structuring element in world politics. The collapse of central planning also implied the collapse of the stark real-world contrast between market and hierarchy.

Political authorities virtually everywhere found themselves experimenting with a range of alternative arrangements? governance structures that were neither pure market nor pure hierarchy in nature (Hirst, Hollingsworth, et. al.). Networks, associations, and regions became more prominent as practical forms for organizing economic activity. In analytic terms, the governance concept provided a bridge for comparing economic and historical types of institutionalism. For political economists, the mixed economy was giving way at a lower level of aggregation to the alternative governance structure. This paper explores the new approaches to industrial governance and then examines public strategies for technological change in Germany in order to determine which approach can best explain this particular case.

The economic concept of governance initially grew out of the dichotomy of market versus hierarchy, developed by Ronald Coase and elaborated by Oliver Williamson. According to this view, certain conditions made it difficult to transact exchanges efficiently through the market. These conditions -- uncertainty, frequency, and asset specificity -- led rational economic actors to remove transactions from the market and internalize them within the firm. Although the transaction-cost approach was by no means the only institutional perspective supplied by economists, it was the one that prompted the main lines of debate among other social scientists.

Political scientists and sociologists responded to the transaction-cost approach by documenting a more differentiated set of governance structures. These include networks, associations, and regions -- all of which provide frameworks for coordinating economic transactions that do not resemble those provided by markets or by hierarchies. Networks delineate

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[1] An earlier version of this paper was presented at the Annual Meeting of the American Pollitical Science Association, Chicago, Illinois, August 31-September 3, 1995.

populations of firms that share privileged trading relations, without the strong authoritative control that characterizes hierarchical structures (Powell). Associations include competing producers whose choices of product lines (and therefore customers) are guided by longer-term negotiated understandings (Campbell, et. al.; Hollingsworth, et. al.) Regions include producer and user firms whose spatial proximity leads to trust-based contracting more readily than might occur without the spatial proximity (Sabel; Saxenian). Scholars disagree about whether these alternative governance structures can ever prove more efficient than markets or hierarchies. Many argue instead that these alternative governance mechanisms are adapted to a broad range of goals -- including industry longevity, political power, and even cultural identity -- in addition to efficiency.

The political approach to sectoral governance also has an independent foundation in the historical literature on economic development. Building on the work of Alexander Gerschenkron, this view argues that political and economic institutions are shaped by the timing of industrialization, and that, once formed, these institutions point countries on path-dependent courses of economic development which emphasize particular sectors at particular phases (Kurth; Gourevitch). According to this view, sectoral governance structures are not selected -- whether on efficiency, political, or cultural grounds -- but are rather dictated by prior institutional developments. Institutional change is, in this perspective, understood as a process analogous to punctuated equilibrium, where prior legacies constrain future developments except at fundamental rupture points such as wars or international financial crises (Krasner; Thelen).

While this historical strand of institutionalist analysis provides a very broad perspective on sectoral governance structures, two recent initiatives have focused this perspective more tightly on problems of technological change and policy learning. According to John Zysman, historical institutions not only set the broad outlines of economic development; they also create a mutually reinforcing set of public policies and corporate strategies that keep countries on distinctive technology trajectories. Herbert Kitschelt argues in complementary fashion that different countries have distinctive organizational capacities which, in turn, render them more or less well adapted to exploit the technologies on which particular sectors hinge. Both of these accounts allow considerable room for learning by government agencies as well as business organizations, but the scope of learning is constrained by prior institutional history.

This paper builds on the perspectives elaborated by Zysman and Kitschelt, but gives them a strong voluntarist twist. In explaining how sectoral governance structures arise, we are not forced to choose between competitive selection processes or

institutional determination. The evidence from German policies for technological innovation suggests a third possibility: intentional policy learning through policy experimentation. Much as Zysman and Kitschelt suggest, the scope of policy learning is constrained by institutional factors. The relevant constraints do not, however, result only from national institutional arrangements. Two additional factors -- company-level institutions of cooperation and the ideational content of policy debate -- can help or hinder policymakers in their efforts to learn from policy experimentation.

German policymakers have displayed a remarkably persistent commitment in recent decades to the goal of technological advance in industry. Whether under Social-Liberal or Christian-Liberal coalitions, the national ministries in Bonn have elaborated a series of policy instruments for promoting innovation in industry. Such policies are a natural case for testing different concepts of industrial governance precisely because one of the central functions of public policy for innovation is to limit the possibilities for opportunism among cooperating firms, that is, to supply governance structures.

This paper argues that German policy efforts to promote innovation exhibit a clear tendency over time. German policymakers have withdrawn steadily from a position of hierarchical control over innovating firms, but may paradoxically have gained in capability to promote innovation. They have done so by relying on the Federal Republic's unusually dense institutional landscape, and, in particular, by selecting from a rich and changing range of possible governance structures.

I. Technology Policy as Constrained Experimentation

Viewed as a process of problem-solving and experimentation, the evolution of public policies for promoting technological change is not well illuminated by monocausal explanations for public policy. The scope of consensus between management and labor suggests that class divisions do not shape patterns of technology policy, at least not in any simple sense. The elements of similarity across sectors also suggests that cross-class coalitions within sectors cannot be the sole determinant of policy.

If anything, monocausal explanations are unpromising because of the many uncertainties that confront public agencies in their efforts to promote technological advance in industry. Technological change includes both innovation (or the first-time commercialization of new technologies) and diffusion (or the dissemination of existing technologies to the enterprises). Whether the goal is innovation or diffusion, however, policies for technological advance confront at least four broad types of

uncertainty: technical, organizational, market, and strategic.[2] These uncertainties mean that a problem-solving approach may be more appropriate for technology promotion than for other areas of economic policy. Indeed, technology promotion in several other countries has hinged on the effectiveness of officials and elites in pursuing a problem-solving approach (Adler).

If German technology policy was best understood as a process of experimentation, however, it was a constrained process shaped by more than the cognitive capabilities of public officials. The same aspects of German politics that allowed officials considerable latitude in allocating public funds for technology also defined the limits of that latitude. This pattern of constrained policy experimentation was shaped by three factors, which fundamentally disrupted any simple class- or sector-driven pattern of policy. First, the elite debate between proponents of active structural policy (Strukturpolitik) and ordoliberalism (Ordnungspolitik) encouraged ministerial officials to devise a broad range of policy instruments. Second, Germany federal structure provided a tailor-made arena for experimentation among subnational jurisdictions. Third, the institutions of social partnership at the plant level obliged managers to adapt technologies to the circumstances of the work process as seen by employee groups in particular settings. This paper documents the interplay of all three factors by surveying the main chrnological phases of technology policymaking, by examining two particular program areas in more depth, and by assessing the possibilities for ongoing experimentation as opposed to more radical discontinuity in post-unification Germany.

II. Historical Overview

As a process of policy experimentation, public efforts to promote technological advance were responses to the external and internal challenges faced by the German polity. As these challenges evolved, technology promotion was institutionalized in the form of a dedicated ministry in Bonn and in the efforts of specialized professionals who implemented ministry's programs and evaluated their results.

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[2] Technical uncertainty refers to difficulty in predicting whether the materials and algorithms available to researchers allow for the solution of the problem at hand. Organizational uncertainty refers to the difficulties of moving such a solution from laboratory to shop-floor, or, more generally, of deploying the solution in a practical setting once it has been discovered. Market uncertainty refers to the variability of market demand for a practical solution once it has been successfully deployed. Finally, strategic uncertainty refers to the possibility (quite important for sponsoring agencies) that a successfully commercialized (or diffused) solution for which demand exists will nonetheless fare poorly in market competition with other substitute products or processes.

In the 1950s and 1960s, federal efforts to promote technological advance in West Germany were framed by the general goals of rebuilding the economy and regaining a degree of autonomy in the international system. Given these goals, general scientific advancement and high-prestige projects in aerospace and civil nuclear power were more prominent than generic industrial innovation (Keck, 1978; Stucke). Only in the late 1960s did the fear of economic domination for foreign multinationals, above all IBM, lead the federal government to introduce a program for electronic data processing (1966) and "new technologies" for industrial applications (1969).

Concern for industrial technologies took greater prominence in 1972, when the Social Democratic Party became the dominant coalition partner in Bonn. The economic significance of technological change was further recognized when a new Ministry for Research and Technology (Bundesministerium für Forschung und Technologie, or BMFT)[3] was established as an institution separate from the Ministry for Education and Science (FAZ, 19 December 1972). In the area of industrial technologies, the new Ministry's mission was to promote structural change by supporting inudstry's efforts to develop and diffuse new technologies. The emphasis was laid on "active" measures rather than mere maintainance subsidies and on relieving "bottlenecks" (Engpässe) to technological change by providing firms with funds to undertake otherwise risky technological changes.[4]

The SPD's new orientation for technology policy provoked vigorous discussion with numerous other actors. German industrial unions, which had taken stances on automation as early as the late 1950s, participated extensively in the policymaking process and obtained a major program for the "humanization of work" to give workers a role in the deployment of new technologies that were supported by the federal government's Technology Ministry (Gielow, Dankbaar). By the late 1970s, the rapid growth of electronics and engineering in Baden-Württemberg and Bavaria highlighted the so-called North-South gradient and meant that the regional effects of Bonn's technology policies were increasingly debated (Bundesbericht Forschung VI, 16). Finally, within the coalition, the SPD's policies were vehemently attacked by the Free Democratic Party chairman, Otto von Lambsdorff, who argued that technology subsidies for large firms

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[3] I use the shortened name, "Research Ministry," the acronym, "BMFT," and the colloquial name for the successor Ministry, "Zukunftzministerium," interchangeably.

[4] The best statement of the Ministry's rationale, which became especially trenchant after the recession of 1975-76, was Volker Hauff and Fritz W. Scharpf, Modernisierung der Volkswirthschaft: Technologiepolitik als Strukturpolitik (Frankfurt/M: Europäische Verlagsanstalt, 1975). Their view was informed by the work of Gerd Mensch. For a broader record of the "policy coordination" impulse, see the dozens of volumes published by the Kommission für Wirtschaftlichen und Sozialen Wandel, published in the early 1970s.

like AEG and Siemens severely disadvantaged Germany's Mittlestand, or small and medium-sized sector.

When the Christian-Liberal coalition took power in 1982, it was confronted with an interesting political dilemma in technology policy. The proponents of ordoliberalism, who expected to gain more policy input, called for dismantling the anticipatory elements of the SPD's technology policy. True to expectation, Heinz Riesenhuber, the charismatic new Minister Research and Technology, called for a new approach to technology policy ("Die Wende in der Technologiepolitik"). At the same time, however, the recession of 1979-1980 had many of the "structural" characteristics that Volker Hauff and Fritz Scharpf had mentioned in their 1975 call for anticipatory technology policy. In particular, many of the Mittlestand sectors that comprised a core constituency for the Christian Lberal coalition were in dire straits. The question of the day was whether the entire mechanical engineering industry would go the way of the watch industry, which had entirely succombed to digital products from the Far East.

These political constraints led Minister Riesenhuber to showcase a relatively new policy instrument, the co-called "indirect-specific" program. This awkward appellation resulted clearly from efforts to resolve the priorities of Strukturpolitik and Ordnungspolitik. Consonant with the goals of active adjustment, the programs were "specific" in that they provided funds for precisely defined generic techologies, mostly in microelectronics. Consonant with the goals of market-led adjustment, the programs were "indirect" in that the Ministry did not pick recipients and in fact delegated implementation entirely to external non-state agencies (Trägerorganisationen). The Social Democrats had themselves recognized the need to promote small and medium-sized firms through indirect measures (Hauff and Scharpf, pp. 55-56) and had instituted the first indirect-specific program for microelectronics in 1979. Because the indirect-specific measures were a politically convenient way for the Christian Democrats to promote technological adjustment within the Mittelstand, they extended this approach from microelectronics to production technologies (Fertigungstechnik), sensor technology (Mikroperipherik), and micro-machine systems (Mikrosystemtechnik).

While shifting the Ministry's rhetoric toward those policy instruments that most nearly resembled the market-conforming ideal of ordoliberalism, the Christian-Liberal coalition could not significantly alter the range of interlocutors involved in the policy process. Not only individual firms, but industry associations and trade unions were represented in the Technology Ministry's advisory boards for particular programs (BMFT, "Beratungsübersichte, various years). Although the unions did not enjoy the same access to party deliberations that they had in

the Social-Liberal years, they were granted the same rights to consultation that German administrative procedure accorded all target groups during the drafting of legislation.

If the scope of policy discussion remained constant during the 1980s, the extent of subnational experimentation in technology policy increased dramatically during the decade. The two conservative Minister Presidents in Germany's affluent South -- Lothar Späth in Baden-Württemberg and Franz Joseph Strauss in Bavaria -- engaged in a celebrated competition for investments in electronics and aerospace. In the North, Länder governments in North Rhine Westfalia and Lower Saxony, experimented with a range of strategies and local institutions aimed at revitalizing the so-called rustbelt sectors.

In the period following unification, the Research Ministry took a backseat in addressing the immediate issues of unemployment, property rights, and economic restructuring. Within the Ministry's own brief, the tasks of reforming the East's universities and basic research institutions were considerably more important than promoting industrial innovation in firms which were struggling simply to find new markets for existing product lines. Indeed, Minister Riesenhuber, who had been so prominent in Chancellor Kohl's early cabinets played a largely reactive role and left the cabinet not long after unification, to be replaced by a new party member from the East. Following the elections of 1994, pressure to cut administrative costs in the federal government led the coalition to merge the Research Ministry back into the Education Ministry, giving the combined entity the official name, Federal Ministry for Education, Science, Research, and Technology, colloquially known as the Ministry for the Future (<u>Zukunftsministerium</u>).

While the visibility of technology policy as a cabinet function declined, Chancellor Kohl himself assumed a more prominent role in coordinating discussions on technology. At the international level, Kohl appointed Heinz Riesenhuber to chair two high-profile councils, one to promote scholarly exchange with the United States and the other to focus particularly on technology exchange with Japan. As part of the domestic <u>Standortdebatte</u> (the debate on Germany as an investment site), the Chancellor also inaugurated a high-profile "Technology Council." The new Council -- charged with discussing interdisciplinary and interministerial problems in Germany's research and innovation infrastructure -- included academics, industrialists, and union representatives. The SPD criticized the new council as a purely "symbolic" means of circumventing serious discussion among the social interest groups (Süddeutsche Zeitung, 23 March 1995), but orthodox economic liberals in the Economics ministry took the new Council as a more serious threat to reaasert the state's role in technological change (Süddeutsche Zeitung, 1 October 1994).

III. Cases

These general tendencies reveal little about the underlying mechanisms of policy change, simply because they are not sufficiently fine-grained to illuminate whether policy feedback or policy learning are occurring (Hall; Pierson). In order to illuminate how the process of policy change occurred, the following discussion reviews successive programs in two areas: automated manufacturing technologies and semiconductors.

A. Production Technologies

Germany's status as workshop to the world in the 1960s and 1970s focused wide concern on the country's capital-goods sector in the 1970s. As key supplier to the vast metalworking industry, the capital goods sector was essential to the health of Germany's entire manufacturing economy. The task of upgrading the capital-goods sector involved numerous actors, but the Federal Research Ministry played a central role by bringing the different actors together and publicizing the importance of the problem. In so doing, the Ministry devised a series of policy instruments that represented different degrees of compromise between the goals of Strukturpolitik and Ordnungspolitik.

In the 1970s, the Ministry for Research and Technology promoted technologies for automating production through direct grants. These grants went to enterprises and the major technical universities in Aachen, Berlin, Munich, Stuttgart and other cities for studies in computer-aided development, planning, and process control. This "direct" approach prompted the same critiques of anticipatory technology that were heard more widely from the industrial associations, the chambers of commerce, and other representatives of the Mittelstand.[5]

In the mid-1980s, the Ministry shifted its promotion of production technologies toward the new, so-called "indirect-specific" measures that had been introduced a few years earlier for the dissemination of microelectronics through the small-firm sector. The first such program for production technologies (Fertigungstechnik) subsidized 40% of a firm's expenses for adopting computer-aided production technologies. The provision limiting disbursements to any single firm to 300,000 DM over the period, 1984-1988, clearly made the program more suitable for small firms than for large concerns (BMFT, Bundesbericht Forschung 1984, 125).

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[5] For examples, see Otto Wolff von Amerongen, head of the Chambers of Commerce, quoted in the Nürnberger Nachrichten (9 April 1980) and additional debate in the Frankfurter Allgemeine Zeitung (14 June 1980).

The shift toward indirect-specific measures in _Fertigungstechnik_ clearly represented a change in governance structure because the program was administered by a non-state agency in Karlsruhe (_Projektträger Fertigungstechnik, Kernforschungszentrum Karlsruhe_). The non-ministerial staff in Karlsruhe evaluated proposals and also worked with firms in a CAD/CAM laboratory built especially for the program. The Ministry thereby freed itself from the obligation of monitoring each particular project and also strengthened an intermediary organization that itself became a significant reservoir of learning about the practical problems confronted by small firms in automating parts of their production process.

These policy efforts were only one element in a much larger industry-wide debate among enterprise consultants, industrial sociologists, and experts in production engineering. This discussion -- now well-known -- revolved around issues of deskilling and upgrading. Along with efforts to introduce new technologies, industry associations also launched a "qualification offensive" (Kaßebaum, 185 ff.) aimed at upgrading the skills of production personnel. This offensive involved a reclassification of the metalworking professions (see Streeck, et. al.) and a broad debate on the "new production concepts" that should guide the automation process (Kern and Schumann). Although no single viewpoint gained universal acceptance, many perspectives did converge on the view that labor-saving technologies necessitated control by competent and broadly trained employees (Kern, 1995).

The Programm Fertigungstechnik reflected the view that new technologies and enhanced skills necessarily complemented each. According to the guidelines administered in Karlsruhe, all proposal required a minimum of six man-months of training during the prelimariny phase in order to assure adequate firm-level expertise (_personengebundenes Minest-know-how im Unternehmen_). For CAD/CAM projects, the designated personnel could be univeristy engineers, graduate engineers, physicists, technicians, masters craftspersons, or others of similar job classifications. For robotics and automated transfer systems (_Handhabungssysteme_), designated personnel could also come from the ranks of skilled machinists.

Through this broad set of efforts, the instruments of the Research Ministry were well matched to the skills and capabilities available within small and medium-sized firms in Germany. In this respect, the Ministry's _Programm Fertigungs-technik_ reinforced the largely successful movement in the German Mittelstand toward high value-added niche production. The match between policy and firm-level capabilities was critical to this relatively successful policy iteration (Ziegler, 1995).

The most recent case of policy for production technologies began in 1990 with the program for micro-machines, or Mikro-systemtechnik. This program aimed at encouraging the use of manufacturing systems with miniaturized control devices, usually adapted from semiconductor technologies. This program, initially budgetted through 1993, emphasized the indirect-specific measures (described above) as well as a series of joint research projects (Verbundprojekte) among enterprises and research institutions. Like earlier efforts in production technologies, the program for Mikrosystemtechnik was aimed at small firms and emphasized precompetitive research or prototype development.[6]

Also like earlier policy iterations, this program was entrusted to a non-state agency, in this case a Berlin consulting bureau jointly operated by the German Engineering Association asnd the German Association of Electrical Engineers, the VDI-VDE Technologiezentrum Berlin. Since its founding in the 1970s, the VDI-VDE Technology Center had established an autonomous identity with multiple sources of financing and substantial in-house expertise. While much of the Center's work for the indirect-specific measures was formal in nature, the staff's role went well beyond the administrative. In-house experts managed conflicts within the joint research projects and also accumulated practical knowledge of the difficulties faced by small firms in implementing new technologies.

The program was extended from 1994 through 1999 in order to give firms in the New Bundesländer a chance to participate. In the years from 1990 through 1993, only 6% of the proposals for indirect-specific support and 8% of the disbursed funds went to enterprises in the East. Partly for this reason, the second phase, from 1994 to 1999, was expected to rely primarily on joint research projects with incentive funding for projects that joined West German firms with firms and institutes in the New Bundesländer (BMFT, Mikrosystemtechnik, 1994-1999, page 32, 39).

One difference in the Research Ministry's programs in the 1990s and the 1980s concerns context. There is no "qualification offensive" to match the broad effort at upgrading production skills that occurred during earlier programs. While the Programm Mikrosystemtechnik includes mention of training as a possible "bottleneck," the guidelines for the program are directed almost exclusively at university engineers rather than the broad spectrum of job classifications involved in the earlier actions. Ironically, the programs of the 1990s, directed largely at planning and design personnel, may assume a parallel effort in the qualification of production personnel for which no precise equivalent exists in the 1990s.

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[6] Sources include BMFT publications, Pfirrmann (199x), and author interviews at the VDI-VDE Technologiezentrum, 1992 and 1995.

The evolution of policy instruments for production technologies shows progressive refinement since the 1970s, but with little significant adaptation to the circumstances generated by unification. The clearest trend in the Research Ministry's programs is the steadily increasing independence of the intermediary implementing organizations (Trägerorganisationen) that the Ministry itself created to manage its programs for the small-firm sector. In the program for Mikrosystemtechnik, the effort to allocate more funds to recipients in East Germany is also clear. It is, however, difficult to see any change in policy strategies or instruments. The logic of these programs has remained essentially unchanged since the middle of the foregoing decade.

B. Semiconductor Devices

The task of promoting semiconductor technologies posed a more daunting challenge for German policymakers. German industry provided scant foundation for the combination of esoteric design skills, exacting production requirements, and unforgiving market competition that characterized this sector. Since incremental innovation strategies were not likely to succeed in this sector, the fit between indirect promotion policies and the "qualification offensive" that helped German firms upgrade their production processes could not be easily adapted to the requirements of semiconductor industry.

The problem of matching production skills to new technologies is less important in semiconductors than the problem of integrating chip design with the deployment of world-class production equipment. This latter problem concerns considerably more expert professionals -- design specialists, electrical engineers, and production engineers -- than the skilled production workers or controllers involved in most types of metal-based manufacturing. The practices by which leading firms link chip design and the process of "ramping up" production are, not surprisingly, carefully guarded. It is therefore difficult to do more than speculate about the habits of German work organization that might discourage practices congenial to the effective integration of chip design and production.[7]

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[7] It does seem likely, however, that the finely specified skill gradations essential to diversified quality production (Sorge and Streeck) in the 1980s are not as relevant to semiconductor production. There are two reasons. First, the persons involved in ramping up semiconductor production lines are specialized to a degree which, in Germany, allows little reciprocal knowledge of one another's task. In earlier decades, the career of a single German apprentice often went from skilled worker to technician to practical engineer (Sabel, 1982). As a result, persons in these different job classifications often understood one another's work in considerable detail, and, in particular, the more advanced job incumbents had actually experienced the jobs of their less expert colleagues. Since the deployment of semiconductor production equipment entails university education, this earlier model of a career that spans several levels of production and intermediate technical competence is simply less relevant.

Across the entire range of chip production, public officials could gain more leverage by influencing relations among firms than by attempting to influence directly the means by which managers coordinate the activities of design and production specialists. Some semiconductor devices (memories and microprocessors) are commodity products where competition is driven by price and timing. While the chips themselves are commodities, their production depends on clean rooms whose construction requires joint problem solving by highly specialized suppliers. Customized or application-specific integrated circuits (ASICs) require more conventional production equipment, but they embody proprietary designs that can only be entrusted to a chip producer in whom the user firm has great confidence. In both cases, competition hinges on delicate relationships among firms, whether between equipment suppliers and producers or between producers and users. Over the last thirdty years, German public policymakers have settled upon different frameworks at different times for coordinating relationships among the different actors in the industry.

<u>1. The 1960s and 1970s.</u> Chip-producing capacity was first supported through the West German Data Processing Program, begun in 1965. This program was often compared with the "national-champion" strategy of the French state's Plan Calcul, but the parallel was not exact. German efforts in the computer field exemplified the policy style of "rationalist consensus" (Dyson) through which the major players split resources according to a mutually acceptable division of labor. Although Siemens received more funds than any other single firm, the company itself proposed working together with AEG in an <u>Arbeitsgemeinschaft</u> supervised by an outside advisory committee. When policymakers elaborated a more detailed set of objectives for semiconductor components in the early 1970s, funds were again allocated to a number of firms -- including Siemens, AEG-Telefunken, Nixdorf, and Kienzle -- for work in broadly differentiated areas.

<u>2. The 1980s and Megaprojekt.</u> Even as the scale of semiconductor development and production grew, the federal government sought to avoid concentrating its resources on a single firm. The second major iteration of policy toward the chip-making business began in the early 1980s with the so-called "Megaprojekt" -- an effort to produce one-megabyte memory chips by 1988. This program was designed in light of criticisms that earlier policies had left the BMFT too dependent on a single firm. A fact-finding trip to Japan by a Ministry official and a leading independent scientist reinforced the view that German firms were lagging their competitors in semiconductor

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Second, the practices of job rotation and expert teams -- which seem to be involved in the successful "ramping up" of a new chip factory -- do not appear readily compatible with the norms of competence through specialization that characterize German production (Kern and Sabel).

development. Yet, it was well understood that the minimum feasible scale for developing memory chips involved a substantial concentration of funds and manpower.

The BMFT found a novel solution for these contradictory pressures. It again recruited Siemens, the largest and most capable West German firm with a stake in semiconductor production, but Ministry officials collaborated with their Dutch counterparts to bring the Dutch giant, Philips, into the effort. In effect, the Ministry went outside the national community to avoid dependence on a single industrial partner. This arrangement allowed the firms to spread the risk of costly R&D and gave both governments assurance that the firms would be closely monitored by one another. While the BMFT helped Siemens and Philips finance this costly project, it broadened the indirect-specific programs that promoted the diffusion of microelectronics to small and medium-sized firms and bolstered the industry infrastructure by subsidizing several new institutes for applied semiconductor research in the Fraunhofer Society.

<u>3. The Europeanization of Policy toward Semiconductors.</u> Pan-European cooperation in semiconductor production emerged in 1986 though talks between Siemens and Philips about ways of continuing work begun in the Megaproject. Dubbed the Joint European Silicon Structures initiatives (JESSI), the initial idea was to seek support from several European governments in developing future generations of semiconductor products. This proposal quickly encountered resistance from some of Germany's most prominent semiconductor users, who argued that earlier aid to Siemens had only made the firm less responsive to the needs of German chip users. The Nixdorf Computer company argued that the government ought not support microelectronics by helping large chip producers make components for their own use, but should push those producers to satisfy the needs of other large chip users as well. Although Nixdorf was subsequently acquired by Siemens, its argument that Siemens should not be the sole recipient of public support carried considerable weight in the late 1980s.

Throughout the 1980s, Germany's Research Ministry had been receptive to the argument that no single firm could fully represent the public interest in matters of technology. As JESSI took shape, the BMFT became the coordinating agency for the European Planning Group, which included representatives from firms and national governments in five countries (France, Germany, Italy, the Netherlands, and the United Kingdom). The Ministry wanted to make JESSI something more than a collaborative project among Siemens and Philips. At the Ministry's urging, the planning group made four broad categories of projects eligible for JESSI support. Only the first category would include the submicron designs and devices of interest to the three large chip producers. Upstream linkages were to be strengthened through projects including materials and equipment suppliers. Downstream

linkages were also to be strengthened by supporting custom and semi-custom chip users who increasingly wanted their applications designed on single circuits. Finally, longer-term research into materials and techniques was to be supported through a number of European institutes. The national governments required that industrial participants provide at least half the funding for JESSI projects. In providing the other half, government representatives indicated that only 29% would go the submicron chip development, 15% to materials and equipment suppliers, 34% to user applications, and 22% to basic research.[8]

If the BMFT succeeded in pushing the program beyond concentrated subsidies for a few large projects, it also helped involve the EC without ceding administrative control to Brussels. Not surprisingly, the national governments and the firms wanted to involve the Commission as an additional source of public funds. From the viewpoint of officials in Brussels, there was a natural fit between JESSI and such EC programs as ESPRIT. If JESSI were administered through the EC, however, national governments would lose discretion over the specific projects to be included. Officials in Brussels would approve projects and would allocate moneys from the Community's general budget, beyond the control of national technology ministries. In order to circumvent direct EC supervision, the planning group put JESSI under the umbrella of a different European program, EUREKA. Under the EUREKA framework, national governments disbursed funds on a case-by-case basis. The Commission of the European Community could participate in EUREKA, but only as one of the 20 participating governments rather than as supervising body.[9]

Soon after the initial discussions for JESSI got underway, the merged French-Italian firm SGS-Thomson sought entry. Siemens and Philips were reluctant to make their prior development work available to a potential competitor. The dispute was resolved through two means. First, the JESSI framework adopted a complex structure of subordinate boards, in which industry representatives gained access only to the results of projects within their category. In addition, in May, 1990, more flexible conditions on intellectual property were added to JESSI's rules so that participants could request that certain background information be exempted from the usual requirements for disclosure.[10]

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[8] Sources include author interviews at the Federal Ministry of Research and Technology, Bonn, July 1990; the "JESSI Green Book" which resulted from the planning phase (December 1988) and "JESSI soll mittelständische Wirtschaft an die Mikroelektronik heranführen," BMFT Journal (June 1990). A detailed account of JESSI, which reaches more negative conclusions, is provided in Grande and Häusler [1994]. See also Margerum [1994].

[9] Author interviews, Federal Ministry for Research and Technology, July 1990. Author interviews, DG 13, Commission of the European Community, and Cabinet of the President, November 1992.

[10] Author interviews, Siemens, Munich, July 1991.

JESSI's eventual structure was noteworthy for its flexibility. The JESSI board consisted of eight members, all from industrial firms, while governments were represented only in an advisory committee. Each of the four subprograms -- technology, materials and equipment, applications, and long-term research -- also had a management board. Projects could be proposed by any group of participants, providing they represented at least two different countries. The subprogram boards approved projects for inclusion. But approval did not guarantee public funds; it only enabled participants to go to their national governments to apply for funds that had been earmarked for projects with the JESSI label. Officials in the national ministries thus continued to exercise discretion over the specific projects they would fund. In effect, national governments gave up hierarchical control over the technical guidelines of the program in exchange for the opportunity to promote a broader network of firms operating in Europe.

As in earlier iterations of semiconductor policy, German policy makers tried to impose few restrictions on German firms in their choice of technology strategies and partners. Instead, the German Ministry of Research and Technology pushed the major firms to diffuse know-how to other firms operating in Germany. In pursuing this task, German policymakers provided public funds to subsidize the risk of especially costly R&D. At the same time, they painstakingly devised organizational mechanisms that encouraged firms to share risk among themselves. This way of defining the task meant that German officials found it quite acceptable to support Siemens in work that deepened the industry-wide techology base without trying to dictate particular production sites or strategic partners.

4. Unification. The fourth iteration of policy for semiconductors, since unification, signifies a further withdrawal of the federal government from a direct role in bargaining with chip producers over investments or production strategies. During this period, Germany's subnational or Länder governments also emerged as potentially decisive actors in large technology projects. To be sure, the "old" (i.e., West German) Bundesländer had had played a role in supporting the Fraunhofer Institutes and other facilities that contributed to the particular needs of the regional economy. The New Bundesländer exercised some influence on the German federal government's efforts to find Western investors for the former GDR's chip instllations in Erfurt and Ddresden. It was through its ability to unloosen funds from Brussels for greenfield investments, however, that the government in Saxony showed how the regions could become major actors in shaping large technology projects.

In late 1993, Siemens announced its intention to build an integrated center for semiconductor research and production

outside Dresden. According to early announcements, this integrated center would be used for application-specific chips and for producing advanced memory chips. Siemens envisioned investments of 2.5 to 2.7 billion DM to be made over ten years. Production of the 16 megabit chip was to begin in the fall of 1995, with a second fabrication hall to be completed nine months later. Eventually Siemens said it would use the Dresden facilities for producing the 64-megabit and 256 megabit chips that it was then in the process of developing in partnership with IBM and Toshiba.[11]

Public aid for these investments came almost entirely from the structural funds of the European Union. According to EU rules, investments in the new Bundesländer were eligible for a subsidy of up to 35%, or approximately 800 million DM of the total that Siemens envisioned investing. According to press reports, Siemens decided the investments made sense only after extensive negotiations with Saxony's Minister President, Kurt Biedenkopf, whose ability to mobilize funds from Brussels was crucial to the project (Financial Times, December 30, 1993).

These arrangements cast the BMFT in a very interesting role. The Ministry denied any intention of supporting Siemens's investments in production facilities. Since the funding came from Brussels rather than Bonn, the plan needed no approval from the Bundestag or any other agency within the federal government in Bonn. At the same time, it appeared clear that BMFT favored the general thrust of the plan and had conferred quite closely with Siemens and the Landesregierung over the magnitude of state aid that might be available to Siemens for the research projects to be conducted at the Dresden center. One important channel was provided by a BMFT staff member who was seconded to the regional economics Ministry in Dresden.

When pressed by the Bundestag to provide details, the BMFT insisted that it had made no commitment to support any particular research projects in Dresden, but that Siemens's hopes of receiving as much as 300 million DM over a ten-year period were "entirely realistic" (BMFT, 1994). In particular, the Ministry said it could imagine extending work on the "smart fab" program for flexible fabrication, begun under the JESSI framework, to the new center in Dresden. The Ministry had effectively coordinated its research plans with agencies at the supernational level and the subnational level, without taking on any of the political liabilities or financial obligations incurred by those other actors.

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[11] Sources include author interviews, BMFT, July 1994; BMFT, "Bericht ... an den FTTA-Ausschuß." See also Kern and Voskamp.

This division of labor between Bonn and Dresden made the Research Ministry's role more compatible -- at least in formal terms -- with ordoliberal views on technology policy. Ordoliberal writers distinguished between anticipatory instruments designed to promote innovation and technology transfer instruments designed to promote cohesion among economic areas of different levels (Starbatty, et. al.) Since Saxony was eligible for European funds as an underdeveloped region, the plan to build a major center for microelectronics effectively combined anticipatory technology policy with the goals of regional development and cohesion.

In practice, the Landesregierung was pursuing a pragmatic and surprisingly well integrated strategy for regional industrial development. The Dresden government insulated its firms from control by the Treuhandanstalt by establishing its own holding company for consulting and restructuring. As regional Economics Minister, Kajo Schommer, put it, "We do not trust in Bonn or Berlin, but rather in our own experiences here on site."[12] In addition, Schommer emphasized the importance of cooperating with works councils and unions in enterprise restructuring. Even his colleague in the Free Democratic Party, State Secretary Rudiger Thiele, eschewed strict ordoliberal policies, noting that exceptional situations required exceptional treatment. (Süddeutsche Zeitung, 29 August 1994).

Viewed in this context, the Siemens investments were clearly the central pillar in the high-technology side of Saxony's integrated strategy for regional redevelopment. In addition to the Siemens investments, the Saxon government had succeeded in attracting the U.S. chip producer, AMD, to build a factory in Dresden. Two investments of this magnitude meant that a great deal of capital equipment and infrastructure would be brought to the Dresden area. When Applied Materials, one of the premier U.S. semiconductor equipment suppliers, announced its intention to open a branch in Dresden, the door toward a longer-lasting process of agglomeration appeared open.

German policy efforts for semiconductors, like those for production technologies, showed a clear pattern of experimenting with different governance structures. In the case of semiconductors, successive iterations of policy displayed a steady move away from hierarchical control toward network-type relations with industrial firms. This change became evident in the JESSI program, which quickly adopted an explicit network form. At the outset of the JESSI discussion, the boundaries of this network were clearly defined by the state agencies that

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[12] Wir vertrauen nicht auf Bonn oder Berlin, sondern auf unsere Erfahrungen vor Ort. (Süddeutsche Zeitung, 29 August 1994).

provided funding. Rather quickly, however, the firms and research institutes that comprised the JESSI board were empowered to decide which projects would receive the JESSI label. The network therefore became "permeable," with network members themselves deciding on a case by case basis which other firms should be included. Decisions on public financing remained with the sponsoring governments, but the government agencies ceded direct control over membership in the network of participating JESSI organizations.

In the final iteration of policy examined here, it was the subnational government and the European Union that together made the decisive allocation of investment funds. As in JESSI, the Research Ministry in Bonn restricted its role to one of promising resources for collaborative research projects to be approved in the future. In contrast to its role in JESSI, however, the BMFT abandoned a voice in the planning of the Dresden project altogether. By withdrawing from the crucial allocation decisions, the BMFT showed that sovereign national actors could shape technological innovation more effectively by providing governance structures within which other actors cooperate than by supporting specific technologies or innovation strategies. Here the national agency intentionally took a subordinate role in a complex multi-level governance structure where firms and non-national political agencies predominated.

In this sense, unification created room for a degree of policy experimentation that would not otherwise have been possible. Prior to unification, it would have been difficult for the BMFT to find sites or industrial partners that were simultaneously eligible for European cohesion funds and capable of deepening the industrial infrastructure within national boundaries. The goals of national technology promotion were accomplished as part of a strategy for subnational regional development.

IV. Conclusion

Through the policy efforts summarized above, German officials have simultaneously responded to shifting pressures of coalition politics and displayed a persistent process of policy learning. The Research Ministry has settled upon a mix of instruments for maintaining and upgrading different types of technical competence in Germany. This definition of the policy task relieves the federal government of the need to "pick winners." Rather than bargaining over particular strategies or commercial investments, the Research Ministry subsidizes R&D in ways that encourage firms to extend -- and deepen -- the technology base available in Germany. Several implications follow from this definition of the policy task.

This policy approach involves no effort to create rent-seeking advantages and, indeed, does not hinge directly on success in the marketplace. Yet the range of outcomes is not as wide as would be allowed through purely market-conforming incentives. Policy is aimed at reinforcing know-how within geographic limits. The Research Ministry seeks to make Germany a favorable place for firms to invest in R&D and to locate operations, but leaves product decisions and commercial investments to the firms or to other political agencies.

Increasingly, this policy approach entails the conscious design of governance structures that remove the federal government from a position of hierarchical authority but that specify allowable relations among the firms and institutes whose research the federal government will support. In policy for production technologies, the BMFT steadily delegated more authority to the non-state implementing organizations (Trägerorganisationen) for managing programs and resolving conflicts among cooperating firms. In policy for semiconductors, the BMFT quite dramatically removed itself as a participant in investment planning and was content to transmit information between nominally subordinate and superordinate jurisdictions.

The selection of these governance structures is, however, not necessarily efficient. Nor is it driven entirely by any particular doctrine. It instead displays a mix of genuine policy learning that occurs within an ideational context defined by the sometimes esoteric debate between advocates of Strukturpolitk and Ordnungspolitik. As a result, the process may best be described as one of constrained experimentation.

As such, this process of policy learning provides no guarantee of success, only a weak convergence on increasingly effective instruments. One of the requirements for policy learning through experimentation is the political latitude for making mistakes -- a latitude that may decline as pressure on Germany's federal budget grows. In addition, since policy experiments occur in the world of politics rather than the laboratory, success may hinge on contextual factors that cannot be replicated or perpetuated. The policies for production technologies that worked relatively well in the 1980s rested on a process of deliberative consultation, which obliged management and labor to negotiatve at many levels over the design and deployment of new production technologies. This same process characterized the "qualification offensive" that promoted a general upgrading of production skills during the 1980s.

The question therefore arises whether the Federal Republic will face a mismatch between the technologies implemented in the 1990s and the capabilities being brought to the workplace. This risk may be growing as production technologies rely more on the

advanced expertise of design and planning personnel, whose links to shop-floor operators are tenuous. The risk of mismatches may be even greater, according to some observers, in the service industries, because the communication and interactive capabilities required by the new service environments are barely provided at all by existing institutions for white-collar vocational training (Baethge, 1995).

Through the process of constrained experimentation, German officials have devised policy instruments that minimize the risks of opportunism involved in hierarchical relations with industrial partners. By relying on delegated authority and network structures, the Ministry has clearly found ways of encouraging firms to share valuable know-how with other organizations, whether suppliers or users or competitors. It is less clear, however, that the Ministry has found ways of matching its current policy instruments to the human resources that firms can muster as they attempt to build on the niche strategies that were so successful in past decades.

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